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(54) Title: ENHANCED SLEEP MODE IN RADIOCOMMUNICATION SYSTEMS

(57) Abstract

A method and system for providing an enhanced sleep mode for remote units (120) in a radiocommunication system are described. Measurement periodicity for control channels (600) of neighboring cells is optimized. Paging frame (PF) classes can also be temporarily modified to extend sleep periods.

ENHANCED SLEEP MODE IN RADIOCOMMUNICATION SYSTEMS

The disclosure of U.S. Patent Application No. 08/147,254 entitled "A Method for Communicating in a Wireless Communication System", filed on November 1, 1993, is incorporated in this application by reference.

BACKGROUND

5   Applicant's invention relates generally to radiocommunication systems and more particularly to radiocommunication systems in which evaluations of remote unit servers for potential control channel reselection are performed.

The growth of commercial radiocommunications and, in particular, the explosive growth of cellular radiotelephone systems have compelled
10   system designers to search for ways to increase system capacity without reducing communication quality beyond consumer tolerance thresholds. One way to increase capacity is to use digital communication and multiple access techniques such as TDMA, in which several users are assigned respective time slots on a single radio carrier frequency.

15   In North America, these features are currently provided by a digital cellular radiotelephone system called the digital advanced mobile phone service (D-AMPS), some of the characteristics of which are specified in the interim standard IS-54B, "Dual-Mode Mobile Station-Base Station Compatibility Standard", published by the Electronic Industries Association
20   and Telecommunications Industry Association (EIA/TIA). Because of a large existing consumer base of equipment operating only in the analog domain with frequency-division multiple access (FDMA), IS-54B is a dual-mode (analog and digital) standard, providing for analog compatibility in tandem with digital communication capability. For example, the IS-54B
25   standard provides for both FDMA analog voice channels (AVC) and TDMA digital traffic channels (DTC), and the system operator can dynamically replace one type with the other to accommodate fluctuating traffic patterns among analog and digital users. The AVCs and DTCs are implemented by frequency modulating radio carrier signals, which have frequencies near 800

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megahertz (MHz) such that each radio channel has a spectral width of 30 kilohertz (KHz).

In a TDMA cellular radiotelephone system, each radio channel is divided into a series of time slots, each of which contains a burst of information from a data source, e.g., a digitally encoded portion of a voice conversation. The time slots are grouped into successive TDMA frames having a predetermined duration. The number of time slots in each TDMA frame is related to the number of different users that can simultaneously share the radio channel. If each slot in a TDMA frame is assigned to a different user, the duration of a TDMA frame is the minimum amount of time between successive time slots assigned to the same user.

The successive time slots assigned to the same user, which are usually not consecutive time slots on the radio carrier, constitute the user's digital traffic channel, which may be considered a logical channel assigned to the user. As described in more detail below, digital control channels (DCCs) can also be provided for communicating control signals, and such a DCC is a logical channel formed by a succession of usually non-consecutive time slots on the radio carrier.

According to IS-54B, each TDMA frame consists of six consecutive time slots and has a duration of 40 milliseconds (msec). Thus, each radio channel can carry from three to six DTCs (e.g., three to six telephone conversations), depending on the source rates of the speech coder/decoders (codecs) used to digitally encode the conversations. Such speech codecs can operate at either full-rate or half-rate, with full-rate codecs being expected to be used until half-rate codecs that produce acceptable speech quality are developed. A full-rate DTC requires twice as many time slots in a given time period as a half-rate DTC, and in IS-54B, each radio channel can carry up to three full-rate DTCs or up to six half-rate DTCs. Each full-rate DTC uses two slots of each TDMA frame, i.e., the first and fourth, second and fifth, or third and sixth of a TDMA frame's six slots. Each half-rate DTC uses one time slot of each TDMA frame. During each DTC time slot, 324

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bits are transmitted, of which the major portion, 260 bits, is due to the
speech output of the codec, including bits due to error correction coding of
the speech output, and the remaining bits are used for guard times and
overhead signalling for purposes such as synchronization.

5   It can be seen that the TDMA cellular system operates in a buffer-
and-burst, or discontinuous-transmission, mode: each mobile station
transmits (and receives) only during its assigned time slots. At full rate, for
example, a mobile station might transmit during slot 1, receive during slot 2,
idle during slot 3, transmit during slot 4, receive during slot 5, and idle
10   during slot 6, and then repeat the cycle during succeeding TDMA frames.
Therefore, the mobile station, which may be battery-powered, can be
switched off, or sleep, to save power during the time slots when it is neither
transmitting nor receiving. In the IS-54B system in which the mobile does
not transmit and receive simultaneously, a mobile can sleep for periods of at
15   most about 27 msec (four slots) for a half-rate DTC and about 7 msec (one
slot) for a full-rate DTC.

           In addition to voice or traffic channels, cellular radiocommunication
systems also provide paging/access, or control, channels for carrying call-
setup messages between base stations and mobile stations. According to
20   IS-54B, for example, there are twenty-one dedicated analog control channels
(ACCs), which have predetermined fixed frequencies located near 800 MHz.
Two frequency bands, each about 25-MHz wide (the A- and B-bands), are
provided for transmission and reception. The AVCs and DTCs are also
located within the A- and B-bands. Since these ACCs are always found at
25   the same frequencies, they can be readily located and monitored by the
mobile stations.

           It will be understood that a communication system that uses ACCs
has a number of deficiencies. For example, the format of the forward
analog control channel specified in IS-54B is largely inflexible and not
30   conducive to the objectives of modern cellular telephony, including the
extension of mobile station battery life. In particular, the time interval

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between transmission of certain broadcast messages is fixed and the order in which messages are handled is also rigid. Also, mobile stations are required to re-read messages that may not have changed, wasting battery power. These deficiencies can be remedied by providing a DCC, one example of which is described in U.S. Patent Application No. 07/956,640 entitled "Digital Control Channel", which was filed on October 5, 1992, and which is incorporated in this application by reference. Using such DCCs, each IS-54B radio channel can carry DTCs only, DCCs only, or a mixture of both DTCs and DCCs. Within the IS-54B framework, each radio carrier frequency can have up to three full-rate DTCs/DCCs, or six half-rate DTCs/DCCs, or any combination in-between, for example, one full-rate and four half-rate DTCs/DCCs. As described in this application, a DCC in accordance with Applicant's invention provides a further increase in functionality.

In general, however, the transmission rate of the DCC need not coincide with the half-rate and full-rate specified in IS-54B, and the length of the DCC slots may not be uniform and may not coincide with the length of the DTC slots. The DCC may be defined on an IS-54B radio channel and may consist, for example, of every n-th slot in the stream of consecutive TDMA slots. In this case, the length of each DCC slot may or may not be equal to 6.67 msec, which is the length of a DTC slot according to IS-54B. Alternatively (and without limitation on other possible alternatives), these DCC slots may be defined in other ways known to one skilled in the art.

Also, U.S. Patent Application Serial No. 07/956,640 also shows how a DCC may be defined alongside the DTCs specified in IS-54B. For example, a half-rate DCC could occupy one slot and a full-rate DCC could occupy two slots out of the six slots in each TDMA frame. For additional DCC capacity, additional half-rate or full-rate DCCs could replace DTCs. In general, the transmission rate of a DCC need not coincide with the half-rate and full-rate specified in IS-54B, and the length of the DCC time slots

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need not be uniform and need not coincide with the length of the DTC time slots.

FIG. 1 shows a general example of a forward DCC configured as a succession of time slots 1, 2, . . . , N, . . . belonging to a particular DCC. These DCC slots may be defined on a radio channel such as that specified by IS-54B, and may consist, for example, of every n-th slot in a series of N consecutive slots. Each DCC slot has a duration that may or may not be 6.67 msec, which is the length of a DTC slot according to the IS-54B standard. The DCC slots shown in FIG. 1 are organized into superframes (SF), and each superframe includes a number of logical channels that carry different kinds of information. One or more DCC slots may be allocated to each logical channel in the superframe.

FIG. 1 also shows an exemplary downlink superframe, which includes at least three logical channels: a broadcast control channel (BCCH) including six successive slots for overhead messages; a paging channel (PCH) including one slot for paging messages; and an access response channel (ARCH) including one slot for channel assignment and other messages. The remaining time slots in the exemplary superframe of FIG. 1 may be dedicated to other logical channels, such as additional paging channels PCH or other channels. Since the number of mobile stations is usually much greater than the number of slots in the superframe, each paging slot is used for paging several mobile stations that share some unique characteristic, e.g., the last digit of the MIN.

For purposes of efficient sleep mode operation and fast cell selection, the BCCH may be divided into a number of sub-channels. U.S. Patent Application No. 07/956,640 discloses a BCCH structure that allows the mobile station to read a minimum amount of information when it is switched on (when it locks onto a DCC) before being able to access the system (place or receive a call). After being switched on, an idle mobile station needs to regularly monitor only its assigned PCH slots (usually one in each superframe); the mobile can sleep during other slots. The ratio of the

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mobile's time spent reading paging messages and its time spent asleep is controllable and represents a tradeoff between call-set-up delay and power consumption.

As such hybrid analog/digital systems mature, the number of analog users should diminish and the number of digital users should increase until all of the analog voice and control channels are replaced by digital traffic and control channels. When that occurs, the current dual-mode mobile terminals can be replaced by less expensive digital-only mobile units, which would be unable to scan the ACCs currently provided in the IS-54B system. One conventional radiocommunication system used in Europe, known as GSM, is already an all-digital system, in which 200-KHz-wide radio channels are located near 900 MHz. Each GSM radio channel has a gross data rate of 270 kilobits per second and is divided into eight full-rate traffic channels (each traffic time slot carrying 116 encrypted bits).

Digital control and traffic channels are also desirable for other reasons described in U.S. Patent Application No. 08/147,254, entitled "A Method for Communicating in a Wireless Communication System", which was filed on November 1, 1993, and which is incorporated in this application by reference. For example, they support longer sleep periods for the mobile units, which results in longer battery life. Although IS-54B provides for digital traffic channels, more flexibility is desirable in using digital control channels having expanded functionality to optimize system capacity and to support hierarchical cell structures, i.e., structures of macrocells, microcells, picocells, etc. The term "macrocell" generally refers to a cell having a size comparable to the sizes of cells in a conventional cellular telephone system (e.g., a radius of at least about 1 kilometer), and the terms "microcell" and "picocell" generally refer to progressively smaller cells. For example, a microcell might cover a public indoor or outdoor area, e.g., a convention center or a busy street, and a picocell might cover an office corridor or a floor of a high-rise building. From a radio coverage perspective, macrocells, microcells, and picocells may be distinct from one

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another or may overlap one another to handle different traffic patterns or radio environments. Each of these types of cells has a base station which transmits at least one control channel. Thus, a number of neighboring control channels are present for a mobile or remote unit to evaluate as a

5   possible replacement for the current serving control channel to which it is locked.

Accordingly, both ACCs and DCCs will be periodically evaluated by the mobile station for possible control channel reselection. Conventionally, for example, when in an idle state (i.e., switched on but not making or

10   receiving a call), a mobile station in an IS-54B system tunes to and then regularly monitors the strongest control channel (generally, the control channel of the cell in which the mobile station is located at that moment) and may receive or initiate a call through the corresponding base station. When moving between cells while in the idle state, the mobile station will

15   eventually "lose" radio connection on the control channel of the "old" cell and tune to the control channel of the "new" cell. The initial tuning and subsequent re-tuning to control channels are both accomplished automatically by scanning all the available control channels at their known frequencies to find the "best" control channel. The terms "scan" or "scanning" as used in

20   this document, can refer to, for example, signal strength measurement, actual signal decoding, or any other method of evaluating a signal.

When a control channel with good reception quality is found, the mobile station remains tuned to this channel until the quality deteriorates again. In this way, mobile stations stay "in touch" with the system. The

25   analog (non-slotted) control channels specified in IS-54B require the mobile stations to remain continuously (or at least 50% of the time) "awake" in the idle state, at least to the extent that they must keep their receivers switched on. Thus, these conventional systems typically evaluate candidate control channels for reselection purposes at some predetermined, fixed intervals.

30   According to a more recent innovation in cell reselection disclosed in U.S. Patent 5,353,332 to Raith and Muller, each control channel in each cell

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is configured to broadcast information about the presence, if any, of other cells and the characteristics of those cells including minimum quality criteria, power requirements, etc. Typically, information about the presence of other cells is broadcast about neighboring cells. For instance, a neighboring cell may be adjacent to, overlapping, or non-contiguous from the broadcasting cell. A mobile periodically scans during idle mode the neighboring control channels in the coverage area that the mobile is located in to determine which cell it should be locked to. Each control channel includes a neighbor list. The neighbor list identifies other control channels which mobiles locked to that control channel should periodically evaluate. Thus, a mobile may continuously select cells to be locked to based on the existing location of the mobile and quality criteria (e.g., received signal strength) associated with the cells. The cell to which the mobile may be locked is the cell in which the mobile satisfies the quality criteria associated with the cell.

While in the idle state, and in addition to evaluating control channels as potential reselection candidates, a mobile station must monitor the control channel for paging messages addressed to it. For example, when an ordinary telephone (land-line) subscriber calls a mobile subscriber, the call is directed from the public switched telephone network (PSTN) to a mobile switching center (MSC) that analyzes the dialed number. If the dialed number is validated, the MSC requests some or all of a number of radio base stations to page the called mobile station by transmitting over their respective control channels paging messages that contain the mobile identification number (MIN) of the called mobile station. Each idle mobile station receiving a paging message compares the received MIN with its own stored MIN. The mobile station with the matching stored MIN transmits a page response over the particular control channel to the base station, which forwards the page response to the MSC.

Upon receiving the page response, the MSC selects an AVC or a DTC available to the base station that received the page response, switches on a corresponding radio transceiver in that base station, and causes that

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base station to send a message via the control channel to the called mobile station that instructs the called mobile station to tune to the selected voice or traffic channel. A through-connection for the call is established once the mobile station has tuned to the selected AVC or DTC.

5   As noted above, one of the goals of a digital cellular system is to increase the user's "talk time", i.e., the battery life of the mobile station. To this end, U.S. Patent Application No. 07/956,640 discloses a digital forward control channel (base station to mobile station) that can carry the types of messages specified for current analog forward control channels

10   (FOCCs), but in a format which allows an idle mobile station to read overhead messages when locking onto the FOCC and thereafter only when the information has changed; the mobile sleeps at all other times. In such a system, some types of messages are broadcast by the base stations more frequently than other types, and mobile stations need not read every message

15   broadcast.

While the innovative system described in the aforementioned patent application provides many benefits in terms of efficient sleep mode operation with respect to paging, additional features may be advantageous. For example, it would be advantageous to provide the capability to temporarily

20   reassign a mobile or remote station to a different paging class to provide the flexibility necessary for changing system conditions in a cell specific manner.

SUMMARY

Accordingly to exemplary embodiments of the present invention,

25   mobile or other remote units are able to sleep for longer periods of time, and battery life is extended, by optimizing the periodicity at which the remote unit measures control channels on a neighboring list to determine if a new control channel should replace the serving control channel. According to other exemplary embodiments of the present invention, a paging frame class

30   which has been assigned to the remote unit can be modified so that the

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remote unit monitors the paging channel at intervals which are more battery
conservative based on current communication conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing, and other, objects, features and advantages of the
present invention will be more readily understood upon reading the following
detailed description in conjunction with the drawings in which:

Figure 1 depicts an exemplary forward digital control channel;

Figure 2 shows an example of a hierarchical cell structure;

Figure 3 is a flowchart illustrating control channel measurement
according to an exemplary embodiment of the present invention;

Figure 4 is an illustration of different paging frame classes;

Figure 5 depicts an exemplary SPACH header; and

Figure 6 represents a block diagram of an exemplary cellular mobile
radiotelephone system.

DETAILED DESCRIPTION

According to exemplary embodiments of the present invention, the
measurement periodicity for evaluating control channels for potential
reselection of the serving control channel can be optimized to increase "sleep
time" of the remote unit and extend battery life. Briefly, control channels
are used for setting up calls, informing the base stations about locations and
parameters associated with mobile stations, and informing the mobile stations
about locations and parameters associated with the base stations. The base
stations listen for call access requests by mobile stations and the mobile
stations in turn listen for paging messages.

Future systems will employ additional cells. For example, new
systems may include any combination of macrocells, indoor microcells,
outdoor microcells, public microcells and restricted or private microcells.
new systems therefore will likely be designated to incorporate an increasing
number of control channels. Currently, there are approximately twenty-one

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analog control channels available for a cluster in a typical system employed
in the United States.

FIG. 2 is an exemplary hierarchical, or multi-layered, cellular
system. An umbrella macrocell 10 represented by a hexagonal shape makes
up an overlying cellular structure. Each umbrella cell may contain an
underlying microcell structure. The umbrella cell 10 includes microcell 20
represented by the area enclosed within the dotted line and microcell 30
represented by the area enclosed within the dashed line corresponding to
areas along city streets, and picocells 40, 50, and 60, which cover individual
floors of a building. The intersection of the two city streets covered by the
microcells 20 and 30 may be an area of dense traffic concentration, and thus
might represent a hot spot.

Each of the cells illustrated in Figure 2 will include a base station
transmitting on at least one control channel. Consider the remote station,
e.g., a portable unit, which is travelling down the city streets and up into the
building including picocells 40, 50, and 60. During various portions of this
transit, potentially all of the control channels associated with the umbrella
cell 10, the microcells 20 and 30 and the picocells 40, 50, and 60 may be
transmitted on the neighbor list of control channel candidates for reselection.
Evaluating those control channels to determine if reselection is desirable is
performed by having the remote station scan those channels (e.g., measure
the received signal strength (RSS) or decode portions of the signal).

The periodicity with which a mobile or remote station scans the
control channels in the neighbor list during the idle mode can be controlled
according to exemplary embodiments of the present invention as follows.
Two information elements can be transmitted on the broadcast control
channel (BCCH) for the mobile or remote unit to receive that are related to
this scanning process. A SCANFREQ information element can be sent in
the control channel selection message on the BCCH to inform the mobile or
remote station about a default minimum number of signal strength
measurements to be made per time period, for example, per superframe.

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Alternatively, some default value could be provided without transmitting this information element. For a complete discussion of superframes and hyperframes, the interested reader is referred to U.S. Patent Application Serial No. 08/147,254 incorporated above. Briefly, each superframe
5   includes a complete set of F-BCCH information (i.e., a set of Layer 3 messages), using as many slots as are necessary, and that each superframe begins with a F-BCCH slot. After the F-BCCH slot(s), the remaining slots in each superframe include one or more (or no) slots E-BCCH, S-BCCH and SPACH logical channels. A hyperframe consists of two superframes. Thus,
10 the mobile station will perform a total of SCANFREQ signal strength measurements per superframe regardless of the size of the neighbor list. Alternatively, SCANFREQ can indicate measurements per time interval, e.g., superframe, for each entry in the neighbor list.

The number of measurements made by the mobile station on each
15 control channel in the neighbor list per time interval raises an interesting tradeoff. On the one hand, the more measurements which are made, the more accurate the measurement information will be. On the other hand, the greater the number of measurements, the greater the drain on the mobile or remote unit's battery. Since it may be desirable to allow the mobile to take
20 a greater or lesser number of measurements on particular control channels in the neighbor list to finely balance these competing factors, the default SCANFREQ frequency or rate can be modified by a second parameter, denoted HL_FREQ, as described below.

The HL_FREQ information element is transmitted in the neighbor
25 list. For each entry in the neighboring list there is an associated HL_FREQ information element. If the HL_FREQ is set to HIGH, this particular control channel is to be measured using the default frequency or rate defined by the SCANFREQ parameter. If, on the other hand, the HL_FREQ information element is set to LOW, this particular control channel can be
30 measured, for example, at half the frequency or rate required by the default SCANFREQ parameter. Of course those skilled in the art will recognize

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that the particular assignment of HIGH and LOW values of HL_FREQ to the attributes described above is arbitrary and could be reversed.

For example, consider that the neighbor list contains 16 entries, eight of which have HL_FREQ set to HIGH and eight of which have HL_FREQ set to LOW. If the SCANFREQ parameter is set to be 12 measurements per superframe, then the number of measurements for entries marked as HIGH can be measured at a minimum rate of 12/16 per superframe. For entries marked as LOW, the mobile or remote shall measure these control channels at a minimum rate of (12/16)/2 per superframe. Thus, the total number of measurements in this example per superframe would then be:

$$(12/16)*8 + ((12/16)/2) \times 8 = 9$$

To facilitate sleep mode efficiency for the mobile or remote stations, the basic procedure outlined above can be adjusted by the mobile or remote station to reduce the frequency or rate of measurements required. The following discussion describes three exemplary techniques which may be used by the mobile or remote station to reduce the measurement frequency and thereby minimize battery drain.

The flowchart in Figure 3 illustrates three exemplary tests for reducing the measurement frequency of control channels in the neighboring list as a cumulative procedure such that the measurement frequency can be cumulatively reduced by some factor for each test that is validated. However, those skilled in the art will readily appreciate that these three tests could be used on their own or in various combinations rather than being cumulative as set forth in this exemplary embodiment.

At decision block 600, the first test is implemented by determining if the current control channel has been serving the mobile or remote station for more than a predetermined period of time, for example, one hour. This test can be used, for example, to reduce measurements when the remote station is not moving. If so, then the flow moves to block 610 where the measurement frequency on control channels identified by the neighbor list can be reduced by some predetermined factor, for example, a factor of two.

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If not, then no reduction in the frequency measurement is indicated by this test and the flow moves to 620.

The second exemplary test is based on an average received signal strength (RSS) for the serving control channel and the control channels in the neighbor list. An average received signal strength can be used to provide a statistically accurate representation, as opposed to any one instantaneous measurement which could be skewed due to, for example, Rayleigh fading. For the purposes of this example, assume that the mobile or remote station keeps a running average of the last five signal strength measurements for each measured frequency. Then, the compound test expressed by decision block 620 and 630 is as follows. If the rate of change of the average received signal strength on the serving channel is not less than some predetermined threshold rate, for example, 7 dB over a previous five minutes, then no reduction in the measurement frequency is warranted and the flow moves down to block 650. Otherwise, the flow moves to decision block 630 and it is determined whether the change in the average received signal strength on all of the control channels in the neighbor list is less than some predetermined threshold rate, for example, 7 dB over a previous five minutes. If so, then the measurement frequency or rate of the control channels in the neighbor list can be reduced by some predetermined factor, e.g., two. Otherwise, no reduction in the rate of frequency is warranted. In either case, the flow moves on to the third test at block 650.

Therein, it is determined whether or not the rate of change of a difference between the average received signal strength of the serving control channel and of some specific entry in the neighbor list is less than some predetermined threshold rate, e.g., 10 dB over the last five minutes. If so, then the measurement frequency or rate of the control channels in the neighbor list can then be reduced by a factor, for example, two at block 660. Otherwise, no reduction is warranted and in any event the procedure is then completed.

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The aforedescribed process illustrates exemplary ways in which the number of measurements taken by the mobile or remote station on channels in the neighboring list may be reduced to conserve battery power. As the conditions which triggered the reduction in measurement frequency change

5   so that those conditions no longer hold, then the corresponding reduction in measurement frequency can be revoked. For example, the process illustrated in Figure 6 can be performed periodically, e.g., every minute. Thus, if a mobile had previously reduced its measurement frequency of the control channels on the neighbor list based on satisfaction of the criteria in block

10   600 and, in a subsequent iteration the mobile had changed its serving control channel, the reduction of block 610 would be revoked.

In addition to being "awake" to measure control channels, a mobile or remote station is also awake periodically so that it can receive a page. Specifically, the mobile may be paged at any time, therefore the mobile must

15   be locked to a particular cell in a location area so that the mobile may receive the page. For example, if the mobile has moved out of the location area of a first cell to which the mobile was locked to a second cell in a different location area, a paging request for the mobile will not be heard or received because the mobile switching center, or MSC, will page the mobile

20   over a paging channel available to the location area in which the mobile is registered. Thus, a paging request would not be received by the mobile in the distant location area if it is not registered in that location area. Therefore, the mobile should register with a new base station when entering a new location area.

25   According to exemplary embodiments of the present invention, pages are repeated periodically and the mobile station can be assigned to a paging frame class at registration to take advantage of knowledge of this periodicity to remain asleep longer. Exemplary paging frame classes are illustrated in Figure 4. Therein note that a first paging frame class is defined as being

30   every hyperframe, a second paging frame class spans two hyperframes, a third paging frame class spans three hyperframes, and a fourth paging frame

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class spans four hyperframes. When the mobile stations registers, it can temporarily change its paging frame class to PF_1 until it receives a registration response. If the registration response contains a new paging frame class assignment, then that shall be the assigned paging frame class for

5   the mobile. Otherwise, the mobile can retain the default paging frame class of PF_1.

Having been assigned a paging frame class, either by default or through the registration response, the mobile station shall then awaken to determine if it is being paged more or less frequently based upon its paging

10   frame class. According to exemplary embodiments of the present invention, the system can adjust the frequency with which the mobile station awakens to monitor the paging channel without actually changing the mobile station's assigned paging frame class. This provides a solution to another dilemma facing system designers, i.e., the tension between paging frequency and call-

15   setup delay. Consider that the more frequently a mobile or remote unit is paged, the less call-setup delay there will be. However, the more frequently a mobile can be paged, the more often a mobile must "awaken" to potentially receive a page, resulting in greater battery drain. Thus, during periods such as nighttime hours or other times when communication with the

20   mobile or remote station is expected to be less frequent, exemplary embodiments of the present invention provide a mechanism for allowing the mobile or remote station to sleep longer and take advantage of greater tolerance for call-setup delay.

This is accomplished, for example, by transmitting a paging frame

25   modifier (PFM) from the system to the mobile station in a routinely transmitted overhead message via the digital control channel. One exemplary mechanism for transmitting the PFM is in a header of the SPACH channel, e.g., in every PCH subchannel. The SPACH channel, as described in more detail in the above-incorporated U.S. Patent Application Serial No.

30   08/147,254, carries layer 2 messages which are used to carry point-to-point SMS, paging or ARCH information. An exemplary SPACH Header

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including the PFM bit is illustrated as Figure 5. By adjusting the paging frame class of a mobile or remote unit in this way, a cell specific adjustment can be made (rather than changing paging classes upon registration which requires an entire registration area, i.e., potentially many cells, change) and synchronization can be maintained. Thus, the PFM field is unaddressed in the sense that it is transmitted to every mobile or remote in a cell as opposed to a page which is directed to a particular remote or mobile station.

According to exemplary embodiments of the present invention, the paging frame modifier can comprise a single bit which, if set to binary "0", indicates that the mobile unit should continue to use its assigned paging frame class. If, however, the PFM bit is set to binary "1" then the mobile station will adjust its paging frame class, for example, to the next higher paging frame class. As an example, assume that a mobile station has been assigned to paging frame class 2 (PF_2) such that it monitors its paging channel for a page every other hyperframe. Then, assume that the paging frame modifier bit transmitted on the SPACH channel is subsequently set to binary "1". At this point, the mobile will act as if its assigned paging frame class is PF_3 and will sleep longer until the PFM reverts to "0". Mobiles or remote stations which are asleep when the PFM is changes will nonetheless become quickly aware in their change of paging frame class since, according to this example, the PFM is transmitted as a bit on the SPACH header.

The foregoing has described mobile and base station operation in terms of functional qualities. While specific hardware implementations of such stations *per se* are known to those skilled in the art, a brief example will now be described. FIG. 6 represents a block diagram of an exemplary cellular mobile radiotelephone system, including an exemplary base station 110 and mobile station 120. The base station includes a control and processing unit 130 which is connected to the MSC 140 which in turn is connected to the PSTN (not shown). General aspects of such cellular radiotelephone systems are known in the art, as described by the above-cited U.S. patent applications and by allowed U.S. Patent Application No.

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07/670,237 entitled "Neighbor-Assisted Handoff in a Cellular
Communication System" by Wejke et al., and U.S. Patent Application
No. 07/967,027 entitled "Multi-Mode Signal Processing", both of which are
incorporated in this application by reference.

5   The base station 110 handles a plurality of voice channels through a
voice channel transceiver 150, which is controlled by the control and
processing unit 130. Also, each base station includes a control channel
transceiver 160, which may be capable of handling more than one control
channel. The control channel transceiver 160 is controlled by the control
10   and processing unit 130. The control channel transceiver 160 broadcasts
control information over the control channel of the base station or cell to
mobiles locked to that control channel. It will be understood that the
transceivers 150 and 160 can be implemented as a single device, like the
voice and control transceiver 170, for use with DCCs and DTCs that share
15   the same radio carrier frequency.

        The mobile station 120 receives the information broadcast on a
control channel at its voice and control channel transceiver 170. Then, the
processing unit 180 evaluates the received control channel information,
which includes the characteristics of cells that are candidates for the mobile
20   station to lock on to, and determines on which cell the mobile should lock.
Advantageously, the received control channel information not only includes
absolute information concerning the cell with which it is associated, but also
contains relative information concerning other cells proximate to the cell
with which the control channel is associated, as described in U.S. Patent
25   No. 5,353,332, which is incorporated in this application by reference.

        The above-described exemplary embodiments are intended to be
illustrative in all respects, rather than restrictive, of the present invention.
Thus the present invention is capable of many variations in detailed
implementation that can be derived from the description contained herein by
30   a person skilled in the art. All such variations and modifications are

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considered to be within the scope and spirit of the present invention as defined by the following claims.

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WHAT IS CLAIMED IS:

1.   A method for scanning a plurality of neighboring control channels in a radiocommunication system comprising the steps of:

transmitting, on a control channel which is currently serving a remote station, a default scanning frequency at which said remote station is to scan at least one of said neighboring control channels;

modifying said default scanning frequency based on some predetermined criteria; and

scanning, at said remote station, at least one of said plurality of neighboring control channels at said modified default scanning frequency.

2.   The method of claim 1, further comprising the step of:

transmitting, on said current control channel, a parameter as said predetermined criteria associated with each of said plurality of neighboring control channels which can be used to modify said default scanning frequency or to leave said default scanning frequency unchanged.

3.   The method of claim 2, wherein said parameter is an HL FREQ variable which has a high value when said default scanning frequency is to remain unchanged and a low value when said default scanning frequency is to be reduced.

4.   The method of claim 1, wherein said modifying step further comprises the step of:

reducing said default scanning frequency if said current control channel has been serving said remote station for greater than a predetermined time period.

5.   The method of claim 1, wherein said modifying step further comprises the step of:

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reducing said default scanning frequency if a change of an average received signal strength on said current control channel is less than a first predetermined threshold and a change of an average received signal strength on said neighboring control channels is less than a second predetermined threshold.

6.   The method of claim 5, wherein both said first and second predetermined thresholds are 7 dB over five minutes.

7.   The method of claim 1, wherein said modifying step further comprises the step of:

reducing said default scanning frequency if a change of a difference between an average received signal strength of the current control channel and an average received signal strength of one of said neighboring control channels is less than a predetermined threshold.

8.   The method of claim 7, wherein said predetermined threshold is 10 dB over five minutes.

9.   A base station comprising:

a transmitter for transmitting supervisory data messages on a control channel and for providing neighboring lists to remote units;

said supervisory data messages including an instruction for remote stations to scan at least one control channel identified in said neighboring lists a number of times per some predetermined time period; and

wherein said neighboring lists include a parameter associated with at least one of said control channels identified therein specifying whether said number of times is to remain the same or be reduced for said at least one of said control channels.

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10.   The base station of claim 9, wherein said parameter is an HL
FREQ variable which has a high value when said number of time is to
remain the same and a low value when said number of times is to be
reduced.

5   11.   A mobile station comprising:
                a receiver for receiving supervisory data messages on a
control channel and neighboring lists identifying other control channels;
                means for scanning channels;
                said supervisory data messages including an instruction for
10   said mobile station to scan, at a first rate, at least one of said other control
channels identified in said neighboring lists; and
                wherein said neighboring lists include a parameter associated
with at least one of said control channels identified therein specifying
whether to scan said at least one of said other control channels at said first
15   rate or to scan said at least one of said other channels at said first rate
divided by a predetermined number.

        12.   The mobile station of claim 11, wherein said parameter is an
HL FREQ variable which has a high value when said number of time is to
remain the same and a low value when said number of times is to be
20   reduced.

        13.   A method for commanding a remote station to listen for pages
in a radiocommunication system comprising the steps of:
                providing a plurality of paging frame classes, each class
having a different repeat period for listening for paging messages;
25   assigning one of said plurality of paging frame classes to said
remote station when said remote station registers with said system; and

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transmitting, from said system, a paging frame modifier which commands said mobile to either use said assigned paging frame class or to use a different paging frame class.

14.   The method of claim 13, wherein said different paging frame class is a class having a next highest repeat period relative to said assigned paging class.

15.   The method of claim 13, wherein one of said plurality of paging frame classes has a listening repeat period of every two superframes and another of said plurality of paging frame classes has a listening repeat period of every four superframes.

16.   A method for evaluating a plurality of control channels in a radiocommunication system comprising the steps of:

providing a default frequency of signal strength measurement for at least one of said plurality of control channels to be made by a remote station;

reducing said default frequency for at least one of said plurality of control channels if a current control channel has been serving said remote station for greater than a predetermined time period; and

scanning, at said remote station, said at least one of said plurality of control channels at said reduced frequency.

17.   The method of claim 16, wherein said step of providing further comprises the step of:

transmitting, on said current control channel, said default frequency for scanning by said remote station.

18.   A method for evaluating a plurality of control channels in a radiocommunication system comprising the steps of:

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providing a default frequency of signal strength measurement for at least one of said plurality of control channels to be made by a remote station;

reducing said default frequency for at least one of said plurality of control channels if a of change of an average received signal strength on a current serving control channel is less than a first predetermined threshold and if a change of an average received signal strength on said plurality of control channels is less than a second predetermined threshold; and

measuring, at said remote station, said plurality of control channels at said reduced frequency.

19.   The method of claim 18, wherein said step of providing further comprises the step of:

transmitting, on said current control channel, said default frequency of signal strength measurement to be made by said remote station.

20.   A method for evaluating a plurality of control channels in a radiocommunication system comprising the steps of:

providing a default frequency of signal strength measurement for at least one of said plurality of control channels to be made by a remote station;

reducing said default frequency for at least one of said plurality of control channels if a change of a difference between an average received signal strength of a current serving control channel and one of said plurality of control channels is less than a predetermined threshold; and

measuring, at said remote station, said at least one of said plurality of control channels at said reduced frequency.

21.   The method of claim 20, wherein said step of providing further comprises the step of:

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transmitting, on said current control channel, said default
frequency of signal strength measurement to be made by said remote station.

22.   A base station comprising:
a transmitter for transmitting supervisory data messages on a
control channel and for providing neighboring lists to remote units;
said supervisory data messages including an instruction for
remote stations to modify a default frequency rate at which at least one
control channel identified in said neighboring lists is to be scanned.

23.   A remote station comprising:
a receiver for receiving supervisory data messages on a
control channel and neighboring lists identifying other control channels;
means for scanning said other control channels at a default
scanning rate; and
wherein said neighboring lists include a parameter associated
with at least one of said other control channels identified therein specifying
whether to scan said at least one of said other control channels at said default
scanning rate or to scan at least one of said other channels at said default
scanning rate divided by a predetermined number.

24.   A remote station comprising:
a receiver for receiving supervisory data messages on a
current control channel and neighboring lists identifying other control
channels;
means for scanning said other control channels at a default
scanning rate; and
means for reducing said default scanning rate for at least one
of said other control channels if said current control channel has been
serving said remote station for greater than a predetermined time period.

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25.   The remote station of claim 24, wherein said default scanning rate is received by said receiver in said supervisory data messages.

26.   A remote station comprising:

a receiver for receiving supervisory data messages on a current control channel and neighboring lists identifying other control channels;

means for scanning said other control channels at a default scanning rate; and

means for reducing said default scanning rate for at least one of said other control channels if a change of an average received signal strength on said current control channel is less than a first predetermined threshold and if a change of an average received signal strength on said other control channels is less than a second predetermined threshold.

27.   The remote station of claim 26, wherein said default scanning rate is received by said receiver in said supervisory data messages.

28.   A remote station comprising:

a receiver for receiving supervisory data messages on a current control channel and neighboring lists identifying other control channels;

means for scanning said other control channels at a default scanning rate; and

means for reducing said default scanning rate for at least one of said other control channels if a change of a difference between an average received signal strength of said current control channel and one of said plurality of control channels is less than a predetermined threshold.

29.   The remote station of claim 27, wherein said default scanning rate is received by said receiver in said supervisory data messages.

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30. The method of claim 1, wherein said step of modifying further comprises the step of:

reducing said default frequency if said current control channel has been serving said remote station for greater than a predetermined time period and if a change of an average measured received signal strength on said current control channel is less than a predetermined threshold.

31. A method for scanning a plurality of control channels and a serving control channel by a remote station comprising the steps of:

providing a default scanning frequency for said control channels; and

if said serving control channel has been serving said remote station for greater than a predetermined period of time, then modifying said default scanning frequency for at least one of said serving control channel and said plurality of control channels.

32. The method of claim 31, wherein said at least one of said serving control channel and said plurality of control channels is a control channel provided to said remote station in a neighbor list.

33. The method of claim 31, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels which are provided to said remote station on a neighbor list.

34. The method of claim 31, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels which are provided to said remote station on a neighbor list and said serving control channel.

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35.   A method for scanning a plurality of control channels and a serving control channel by a remote station comprising the steps of:

providing a default scanning frequency for said control channels; and

if a change in an average received signal strength on said serving control channel is less than a predetermined threshold for a predetermined period of time, then modifying said default scanning frequency for at least one of said serving control channel and said plurality of control channels.

36.   The method of claim 35, wherein said at least one of said serving control channel and said plurality of control channels is a control channel provided to said remote station in a neighbor list.

37.   The method of claim 35, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels which are provided to said remote station on a neighbor list.

38.   The method of claim 35, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels which are provided to said remote station on a neighbor list and said serving control channel.

39.   A method for scanning a plurality of control channels and a serving control channel by a remote station comprising the steps of:

providing a default scanning frequency for said control channels; and

if a difference between a change in an average received signal strength on said serving control channel and a change in an average received signal strength on one of said plurality of control channels is less than a

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predetermined threshold for a predetermined period of time, then modifying said default scanning frequency for at least one of said serving control channel and said plurality of control channels.

40.   The method of claim 39, wherein said at least one of said serving control channel and said plurality of control channels is said one of said plurality of control channels.

41.   The method of claim 39, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels.

42.   The method of claim 39, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels and said serving control channel.

43.   A method for scanning a plurality of control channels and a serving control channel by a remote station comprising the steps of:
       providing a default scanning frequency for said control channels; and
       if a change in a difference between an average received signal strength on said serving control channel and an average received signal strength on one of said plurality of control channels is less than a predetermined threshold for a predetermined period of time, then modifying said default scanning frequency for at least one of said serving control channel and said plurality of control channels.

44.   The method of claim 43, wherein said at least one of said serving control channel and said plurality of control channels is said one of said plurality of control channels.

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45.   The method of claim 43, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels.

46.   The method of claim 43, wherein said at least one of said serving control channel and said plurality of control channels includes all of said plurality of control channels and said serving control channel.

47. The method of claim 13, further comprising the step of:
                transmitting said paging frame modifier in every PCH subchannel.

48.   The method of claim 13, wherein said paging frame modifier is an unaddressed information element.

49.   A method for controlling scanning of a plurality of control channels by a remote station comprising the steps of:
        providing a default scanning frequency for said control channels; and
        transmitting a parameter which indicates whether said default scanning frequency is to be modified.

50.   The method of claim 1, further comprising the step of:
        returning to said default scanning frequency after said predetermined criteria is no longer satisfied.

51.   The method of claim 31, further comprising the step of:
        returning to said default scanning frequency if said serving channel is changed.

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52.   The method of claim 35, further comprising the step of:

returning to said default scanning frequency if said change no longer satisfies said condition.

5   53.   The method of claim 39, further comprising the step of:

returning to said default scanning frequency if said change no longer satisfies said condition.

Time →

| SLOT 1 | SLOT 2 | SLOT 3 | SLOT 4 | SLOT 5 | SLOT 6 | SLOT 7 | SLOT 8 | . . . | SLOT # | . . . |

| BCCH | PCH | ARCH | . . . |

|—— superframe ——|

FIGURE 1

FIGURE 2

FIGURE 3

Modify Basic Procedure

600 Is CCHserv the same for > 1 hr.?

Yes → 610 Reduce Meas. Freq. on all CCH_{NL} by factor of 2

No

620 Is $\Delta \overline{RSS}$ on CCH_{SERV} < 7dB/5min.?

No

Yes

630 Is $\Delta \overline{RSS}$ on all CCH_{NL} < 7dB/5min.?

Yes → 640 Reduce Meas. Freq. on all CCH_{NL} by factor of 2

No

650 Is $\Delta(\overline{RSS}_{SERV} - \overline{RSS}_{NL})$ < 10dB/5min.?

Yes → 660 Reduce Meas. on this control channel by factor of 2

No

END
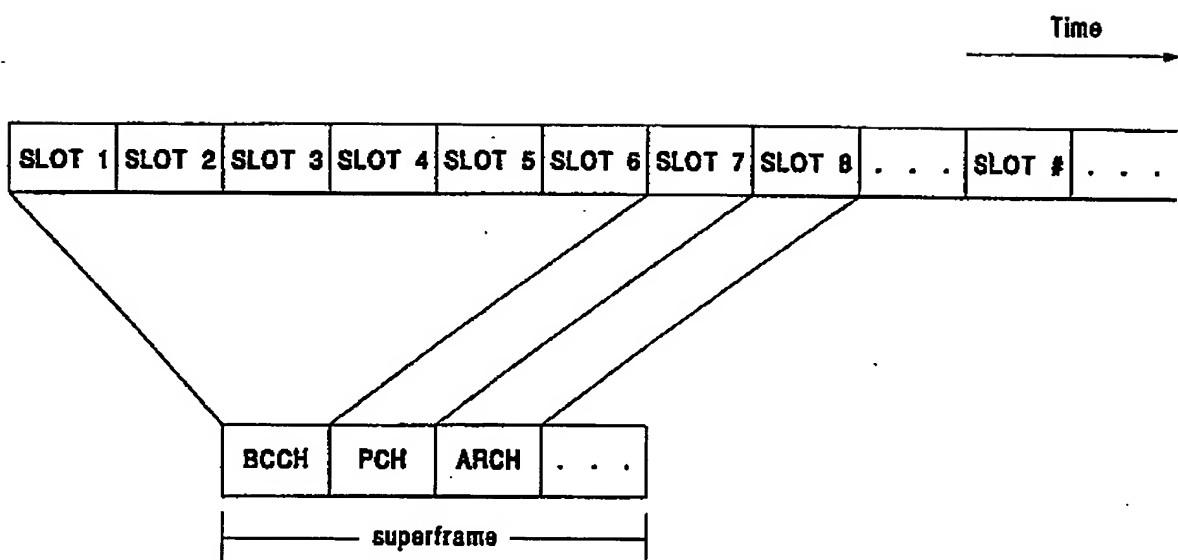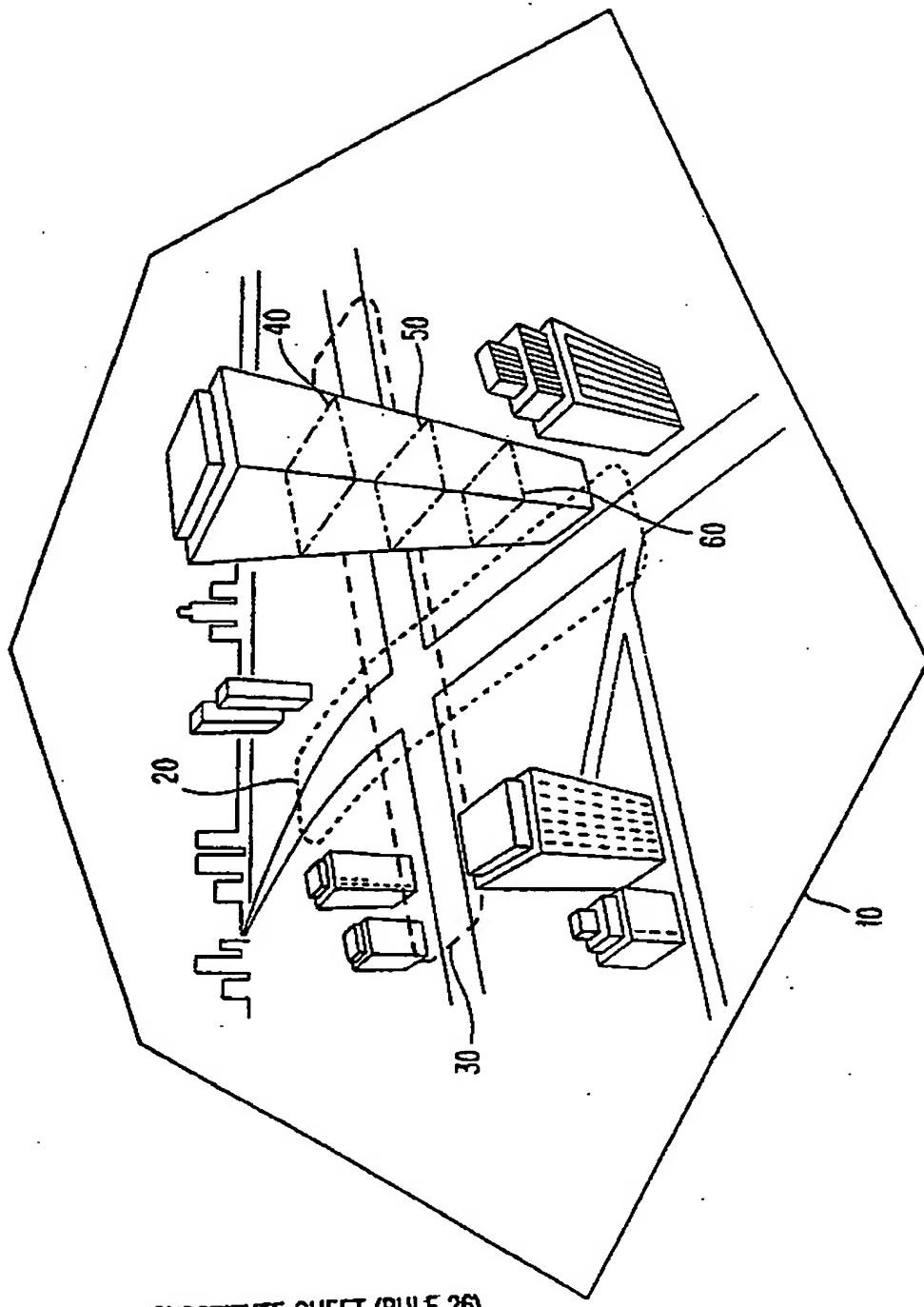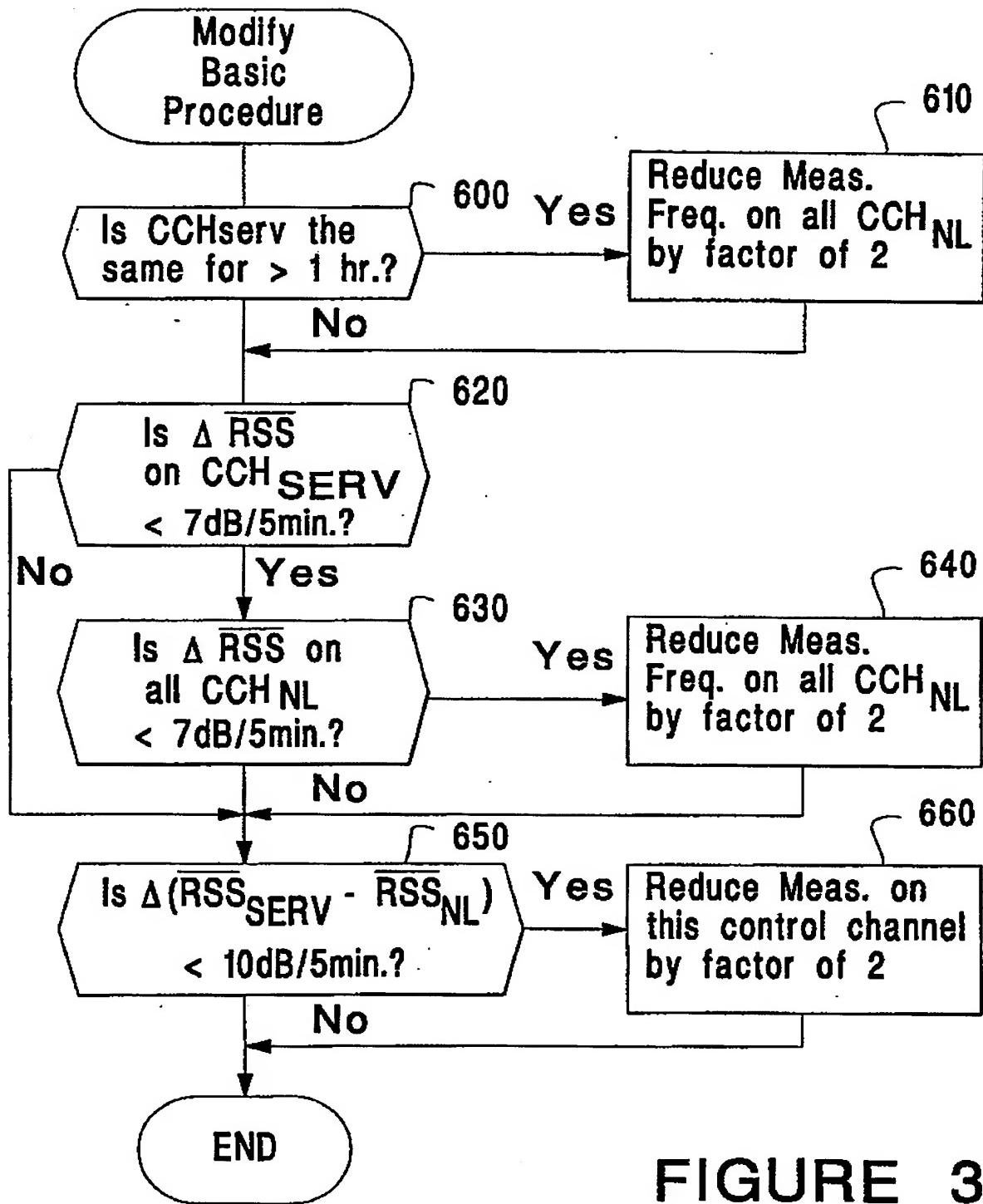
HF$_n$	0		1		2		3		4		5		6	
SF$_n$	0	1	2	3	4	5	6	7	8	9	10	11	12	13
PF$_1$	p	s	p	s	p	s	p	s	p	s	p	s	p	s
PF$_2$	p	s	-	-	p	s	-	-	p	s	-	-	p	s
PF$_3$	p	s	-	-	-	-	p	s	-	-	-	-	p	s
PF$_4$	p	s	-	-	-	-	-	-	p	s	-	-	-	-

←—PF$_1$—→
←———PF$_2$———→
←————PF$_3$————→
←————PF$_4$————→

HF = Hyperframe
SF = Superframe
PF = Paging frame
P = Primary PCHs
S = Secondary PCHs

FIGURE 4

BU =XXX	PCON =X	BCN =X	PFM =X	SMSN =X
3	1	1	1	1

FIGURE 5

FIGURE 6
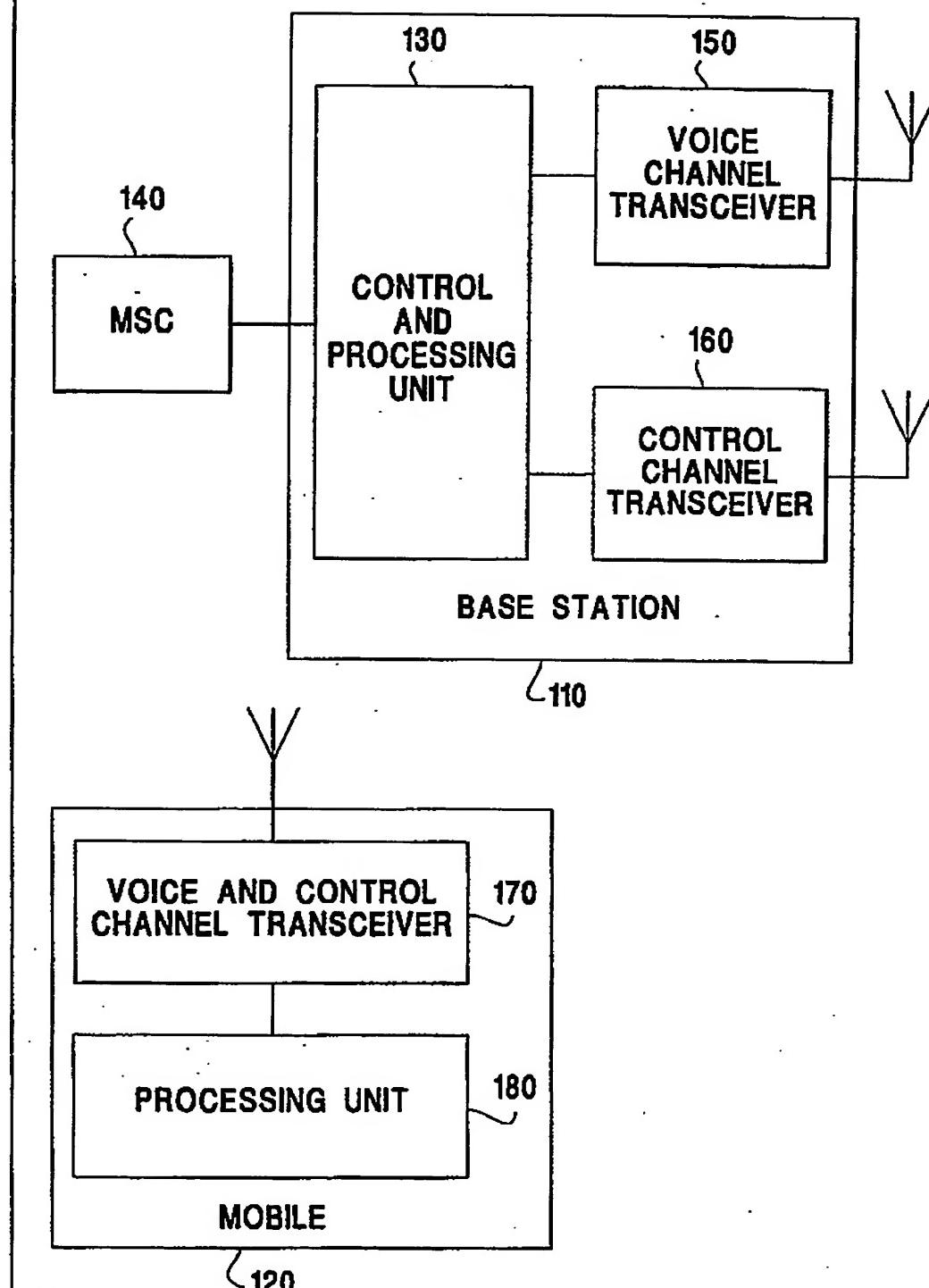
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04J 3/12; H04B 7/00

US CL :370/95.1, 95.3; 455/32.1,38.3,161.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/95.1, 95.3; 455/32.1,38.3,161.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,E	US, A, 5,375,254 (OWEN) 20 DECEMBER 1994, col. 2, lines 27-68, col.3, lines 1-22.	1-53
A	US, A, 5,122,795 (CUBLEY ET AL) 16 JUNE 1992, see entire reference	1-53
A	US, A 5,081,704 (UMEDA ET AL) 14 JANUARY 1992, SEE FIG. 2	1-53

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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		"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 JANUARY 1995	13 MAR 1995

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